Developments in silicon-based opto

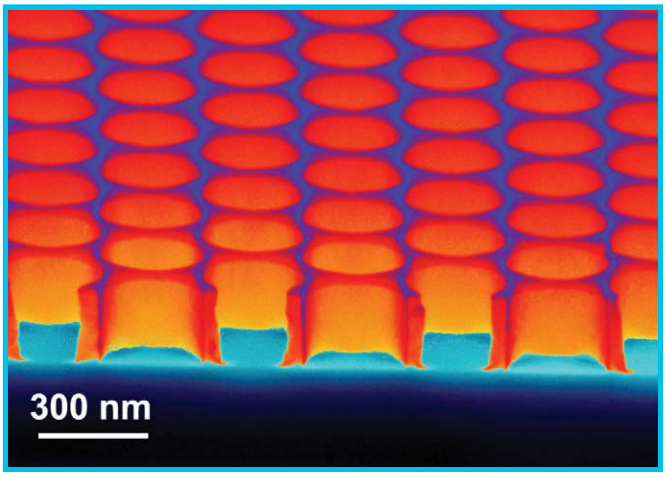
The month of November saw an unusually high number of reports of new developments in silicon-based optoelectronics. These have come from some fairly high-profile institutes and research organisations, leading to the conclusion that III-Vs may have yet another contender to worry about. Long thought of to be the exclusive province of compound semiconductors, a silicon-based laser is once again hitting the headlines (see also page 53). Previous demonstrations have so far not delivered anything like practical performance, but they remain interesting on a technical basis.

Firstly, Translucent Photonics, in Palo Alto, CA, USA, has achieved a 'milestone' in its efforts to develop advanced silicon-based photonics devices. This involves the demonstration of electroluminescence (EL) at room temperature in a form of silicon that is compatible with mass-produced silicon chips, and with future silicon electronics technology nodes.

"Demonstration of electroluminescence at telecommunication wavelengths and room temperature in this new class of silicon-based semiconductors is a significant achievement, and represents a materials science breakthrough for both electronic and photonic applications," says Dr Petar Atanackovic, CEO of Translucent. "This is an important step forward in our optical silicon integration program. The ultimate objective is to develop optically active devices, including an electrically driven silicon laser, which can be integrated with mainstream silicon chips."

The demonstration of EL is a critical pre-requisite to the integration of electronic and optical functionality in silicon, and essentially allows light to be generated from silicon by an electric current, such as would be provided by a small battery or, more importantly, an operating silicon chip itself. The company contends that previous demonstrations of EL in silicon by other groups have been reported at cryogenic temperatures, or in forms of silicon that are not compatible with silicon chips or future technology nodes.

The findings are part of the Electronics and Photonics Integrated Circuits (EPIC) Program funded by DARPA. Under a DARPA contract, begun in January this year, Translucent is funded to develop proprietary silicon-based optical gain devices as part of the broader EPIC Program.
Details can be found at: www.darpa.mil/mto/epic



Micrograph of IBM's SOI photonic crystal. (Courtesy of IBM Research.)

Slowing light down has potential for future circuits

In the current issue of the journal *Nature*, a paper by IBM scientists shows how they were able to slow light down to less than 1/300th of its usual speed by directing it down a carefully designed channel of perforated silicon photonic crystal waveguide (pictured). Its unique design allows the light's speed to be varied over a wide range simply by applying an electrical voltage to the waveguide.

It said that the device could represent a major advance towards the eventual use of light in place of electricity in the connection of electronic components, potentially leading to vast improvements in the performance of computers and other electronic systems.

How to slow light under laboratory conditions has been known for years, but controlling the light speed on a silicon chip made by standard fabrication technology, is a first. The device is tiny uses standard semiconductor materials and good control could make the technology useful for building ultra-compact optical communications circuits that are practical for integration into computer systems.

"This work is an example of our continued commitment to push the limits of exploratory science," said Dr T.C. Chen, vice president of Science and Technology for IBM Research. "We are constantly exploring new technologies that might enhance our systems and storage products. We believe this brings real value to both our clients, who rely on these products to enhance their business, and to their customers, who ultimately benefit from the new and improved services they make possible."

Micron-scale modulator based on silicon

Also in *Nature*, scientists from Stanford University have reported the operation of a micron-scale optical modulator that is compatible with silicon CMOS fabrication techniques. The team are convinced this is an important step in the effort to bring photonics functionality into the world of microelectronics. Previous demonstrations have been involved much larger devices of the order of millimetre and needed high precision, high-Q ring resonators.

Stanford says that the new modulator is a simple system of multiple Ge quantum wells on silicon. A quantum well is a thin layer of semiconductor, in this case a 10 nm-thick slice of germanium, sandwiched between layers of barrier material. The potential energy of carriers in the well is lower than that of carriers in the barrier, and the boundary conditions at the well's edge lead to distinct energy levels of the carriers in the well. These levels can be shifted by an electric field, in an effect known as the quantum-confined Stark effect.

The principle behind the modulator is to Stark-shift one of the levels to an energy exactly right to be excited by an incoming photon. The photon is absorbed, and an electron is boosted from the shifted energy level in the valence band to that in the conduction band. The tricky part is that germanium's bandgap is indirect; meaning that conservation of momentum prohibits a photon with the bandgap energy from boosting an electron from the valence band to the indirect conduction band. The scientists finessed this problem by using a high-energy, direct-bandgap transition to absorb the photon.